www.araner.com

INDUSTRIAL REFRIGERATION

"High-level information for developing the most efficient industrial refrigeration systems"

ARANER

REFRIGERATION

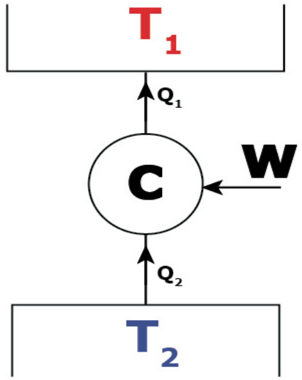
INTRODUCTION

Industrial refrigeration can be defined as the provision of cooling energy to large-scale processes. It embraces a wide range of temperatures, inherent to the purpose it serves, the size of the installation, the equipment's working conditions, etc.

Industrial refrigeration shares common traits with air conditioning: they both have a working fluid and they integrate similar components such as compressors, heat exchangers or pumps. Nevertheless, the most significant difference between them is the scale that it comprises. For air conditioning, the system is usually more standardized, as it is often an extended solution that can be installed like a plug&play package. In the case of industrial refrigeration, the solution is often tailor-made and consequently the design is a complete package.

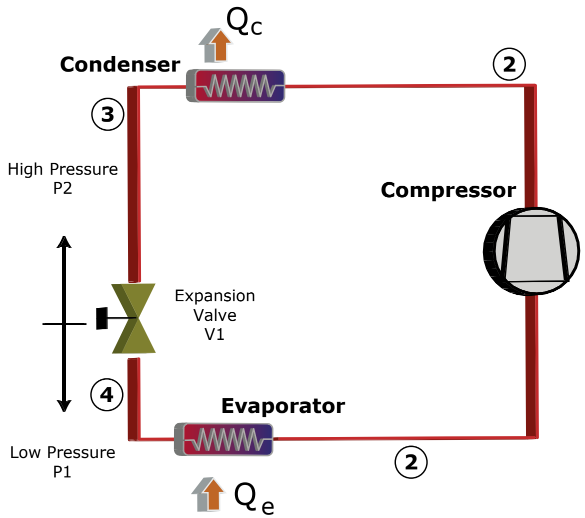
WHAT IS REFRIGERATION?

Refrigeration is a process that consists of lowering the temperature of a given body or space. For two non-isolated systems with different temperatures T1 and T2, where T1 is the hot temperature and T2 the cold temperature, energy passes from T1 to T2 until equilibrium is reached, as stated in the Laws of Thermodynamics. Energy could also pass from the cold temperature system (T2) to the hot temperature one (T1) if work is applied, with a third system intervening in between. This third system will perform the refrigeration cycle.

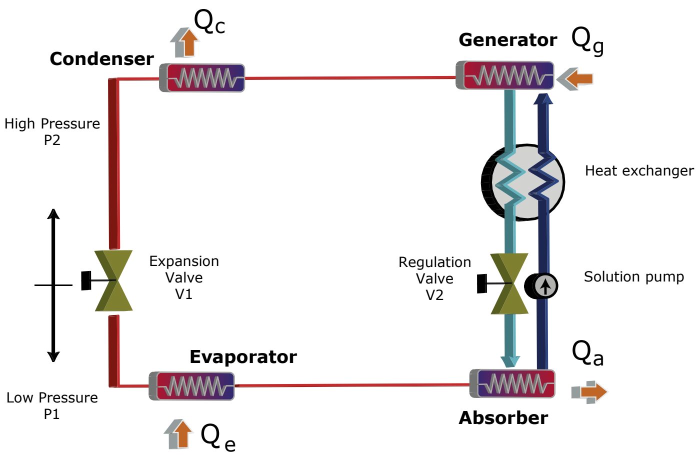


COMPRESSION CYCLE

The refrigerant in the evaporator has a lower temperature than the cold system (T2), so energy is transferred from the cold system to the refrigerant. The refrigerant changes its phase from liquid to gas, since it is absorbing heat. Then the refrigerant is compressed; the rise of pressure causes the refrigerant temperature to rise above the hot system temperature (T1). Therefore, as the refrigerant enters the condenser, energy is transferred from the refrigerant to the hot system. The refrigerant changes its phase from gas to liquid, since it is releasing heat. Afterwards, the pressure is dropped with an expansion valve, making the temperature of the refrigerant lower than the cold system (T2) just like at the beginning of the cycle, to go inside the evaporator again.



ABSORPTION CYCLE



As an alternative to the compression refrigeration cycle, the absorption cycle may be used. The refrigerant, as it goes out of the evaporator, is absorbed by an auxiliary liquid (called absorbent). The pressure rise is done therefore over a liquid fluid by a pump, instead of using a compressor directly over the refrigerant vapor. Pumping the liquid consumes less energy and makes less noise than compressing the refrigerant vapor.

After that, the refrigerant can be separated from the liquid fluid using a heat source. The vapor refrigerant is then obtained and it enters in the condenser, continuing with the normal cycle previously described. On the other side, the liquid fluid is obtained with a poor refrigerant concentration and can be used to re-absorb the refrigerant.

The total energy used in the absorption cycle is higher than the energy used in the vapor refrigeration cycle. However, the form of the energy used is not the same: the vapor cycle uses an electricity input and the absorption cycle uses mainly a heat input and some electricity for the pump and auxiliaries. The electricity used in absorption for some rough estimations may be despicable versus the heat required. The decision of using one or another cycle depends on the availability of heat and electricity resources. Absorption is advisable when low cost heat can be obtained, most often the residual heat from some other process.

REFRIGERANT CLASSIFICATION

INTRODUCTION

The refrigerant should be a fluid capable of operating in the conditions proposed by the refrigeration cycle. The selection of the refrigerant for each situation would depend on its particular conditions with the lowest possible environmental impact. For this reason, there are some refrigerants already banned or with limited use by the authorities. The refrigerants are sorted mainly into two scales:

- **Ozone Depletion Potential (ODP):** the value ranges from 0 (no impact on the ozone layer) and 1 (the most harmful for the ozone layer)
- **Global Warming Potential (GWP):** the value ranges from 0 to several thousands (the higher this value is, the more harmful the refrigerant is for global warming)

Temp. (ºC)	R134a	R717	R744	R410a	
				Liquid	Vapor
	Pressure (barA)	Pressure (barA)	Pressure (barA)	Pressure (barA)	Pressure (barA)
-30	0.84	1.19	14.28	2.7	2.69
-28	0.93	1.32	15.26	2.93	2.92
-26	1.02	1.45	16.29	3.18	3.17
-24	1.11	1.59	17.38	3.44	3.43
-22	1.22	1.74	18.51	3.71	3.7
-20	1.33	1.9	19.7	4.01	3.99
-18	1.45	2.08	20.94	4.32	4.3
-16	1.57	2.26	22.24	4.65	4.63
-14	1.71	2.46	23.59	4.99	4.98
-12	1.85	2.68	25.01	5.36	5.34
-10	2.01	2.91	26.49	5.75	5.73
-8	2.17	3.15	28.03	6.15	6.13
-6	2.34	3.41	29.63	6.58	6.56
-4	2.53	3.69	31.3	7.03	7.01
-2	2.72	3.98	33.04	7.51	7.48
0	2.93	4.29	34.85	8.01	7.98
2	3.15	4.62	36.73	8.53	8.5
4	3.38	4.97	38.69	9.08	9.05
6	3.62	5.35	40.72	9.65	9.62
8	3.88	5.74	42.83	10.25	10.22
10	4.15	6.15	45.02	10.88	10.85
12	4.43	6.59	47.3	11.54	11.5
14	4.73	7.05	49.66	12.23	12.19
16	5.04	7.53	52.11	12.95	12.91
18	5.37	8.04	54.65	13.7	13.65
20	5.72	8.57	57.29	14.48	14.43
22	6.08	9.14	60.03	15.29	15.24
24	6.46	9.73	62.88	16.14	16.09
26	6.85	10.35	65.84	17.02	16.97
28	7.27	10.99	68.92	17.94	17.88
30	7.7	11.67	72.14	18.89	18.84

REFRIGERANT CLASSIFICATION

NATURAL ORGANIC REFRIGERANTS

Organic refrigerants (Hydrocarbon refrigerants – HCs)
Hydrocarbons are called natural refrigerants because they occur in the earth's material cycle, e.g. as a byproduct of natural gas production, or in oil refineries. Chemically speaking, a hydrocarbon HC is an elementary compound of hydrogen and carbon which occurs naturally and is found in large concentrations in crude oil.

The following types of hydrocarbons are commonly used as refrigerants:

- R290 Propane
- R600a Isobutane
- R1270 Propylene

A number of other hydrocarbons, such as blends containing ethane, propane or butane, are also used as refrigerants.

On the one hand, hydrocarbons have excellent thermodynamic properties, and in this respect they are as good as or better than HCF or HCFC refrigerants in most applications. On the other hand, they are highly flammable and must be handled with care. Also, they have zero and negligible GWP (Global Warming Potential).

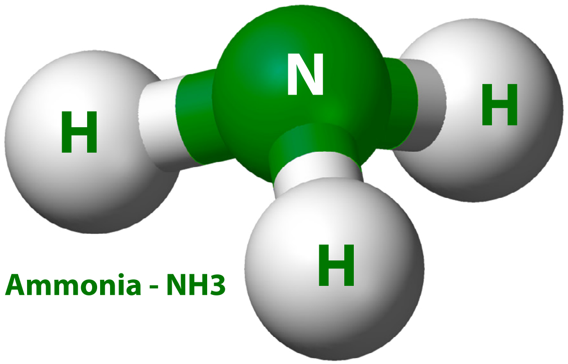
NATURAL INORGANIC REFRIGERANTS

Inorganic refrigerants consist of inorganic compounds (which do not contain a carbon-hydrogen bond) used primarily as refrigerants.

An identifying number shall be assigned to each refrigerant. It consists of a prefix made up of letters and a suffix made up of digits. The prefix is composed of the letter R (for refrigerant). Inorganic compounds shall be assigned a number in the 700 series, identification numbers are formed by adding the relative molecular mass of components to 700.

Ammonia - R717

One of the most used inorganic refrigerants is Ammonia (NH_3), coded R717 as a refrigerant. It has been used successfully over 100 years as a refrigerant, remaining popular even during the strong growth of synthetic refrigerants. Nowadays it is regaining weight as an alternative due to its environmentally friendly properties: it has no ozone depletion potential (ODP=0) and no direct global warming potential (GWP=0).



Ammonia - NH3

Ammonia is a toxic and flammable gas with a pungent odor, which helps in leak detention. However, its ignition energy is 50 times higher than natural gas and it will not burn without a supporting flame. Therefore, a careful handling should be done, together with effective leak prevention and detection.

Carbon Dioxide - R744

Another very common inorganic refrigerant is carbon dioxide (CO_2), coded R744 as a refrigerant. It is considered an environmentally friendly refrigerant, as its ODP is zero and also has a low GWP (around 1). It can be used for a range of applications such as industrial and commercial heating, mobile air conditioning, etc.

The main difference between R744 and other refrigerants is its requirement of high pressures in order to operate efficiently, both in the high- and low-pressure sides of the refrigerant circuit. Therefore, the circuit would have special requirements in order to ensure that it is leak-tight.

REFRIGERANT CLASSIFICATION

SYNTHETIC REFRIGERANTS

Chlorofluorocarbon refrigerants – CFCs

These substances contain carbon, fluorine and chlorine. These refrigerants are already banned from use or production because they have the maximum ODP rate, which it is 1. This includes refrigerants such as R11, R12, R113, R114, R115, etc.

Hydrochlorofluorocarbon – HCFCs

These substances contain hydrogen, carbon, fluorine and chlorine. Their ODP indexes vary between 0.005 and 0.520, and they are considered greenhouse gases. Their use will progressively disappear. This includes refrigerants such as R22, R123, R124, R141b, R142b, R225ca, R225cb, etc.

Hydrofluorocarbon refrigerants – HFCs

These substances contain hydrogen, fluorine and carbon. They do not have ozone depletion potential (ODP=0), but they do act as greenhouse gases. There are no bans on these refrigerants; responsible use and equipment inspections are mandatory under the F-gases regulation. This includes refrigerants such as R32, R125, R134a, R143a, R152a, etc.

MIXTURES OF REFRIGERANTS

Azeotropic refrigerants

They consist of a mixture of two or more refrigerants whose vapor and liquid phases retain identical compositions over a wide range of temperatures.

Zeotropic refrigerants

They consist of a mixture of two or more refrigerants whose vapor and liquid phases differ in their composition. One interesting fact, zeotropic is a word resulting of combining the Greek words zeo (meaning boiling) and tropi (meaning change).

APPLICATIONS

FOOD AND BEVERAGES

Refrigeration is a very important part in the food supply chain. Food can be preserved for a longer time when it is stored at a cold temperature, whether it is frozen or not, so refrigeration should be maintained all the way from the producer to the consumer. Each product has its own optimum storage temperature and conditions.

When foods and beverages are being processed, the product’s key conditions should always be controlled, such as temperature. Oftentimes, the temperature required must be below the ambient temperature, therefore a refrigeration system is required. These products can be sorted into different categories like the ones that are shown below.

FISH

Chilling: It is essential to be chilled down to 0/+2 ºC as fast as possible. It could be carried by one of the following methods:

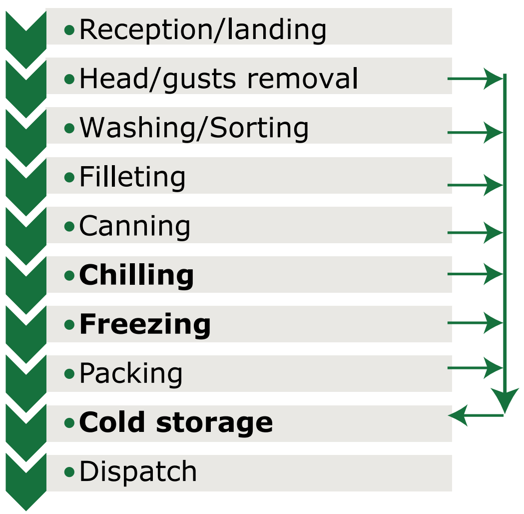
- Mixed with ice: small scale process, suitable for batches. The cooling medium is ice
- Brine tanks (RSW): large scale process, suitable for continuous production. The cooling medium is brine

Freezing: It is cooled down to a minimum of –25 ºC. It could be carried by one of the following methods:

- Plate freezer (contact freezer): large scale process, suitable for continuous production. Plates can be horizontal or vertical
- Batch blast freezer (trolley freezer): small scale process, suitable for batches
- Spiral freezer: large scale process, suitable for continuous production
- Carton freezer: large scale process, suitable for continuous production

Cold storage: It could be stored either chilled or frozen

- Chilled: 0/+2 ºC. Storage life up to 2 weeks
- Frozen: –25/–30 ºC. Storage life up to 12 months



APPLICATIONS

FOOD AND BEVERAGES

POULTRY

Chilling: It is essential to be chilled down to +4 ºC as fast as possible. It could be carried by one of the following methods:

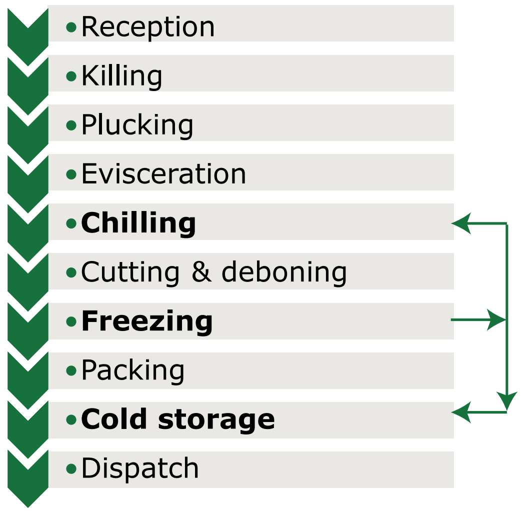
- Blast chilling room: small scale process, suitable for batches. The cooling medium is air
- Blast chilling tunnel: large scale process, suitable for continuous production. The cooling medium is air
- Spin chillers: large scale process, suitable for continuous production. The cooling medium is water with ice (could have salmonella risk)

Freezing: It is cooled down to –18 ºC approximately and needs 10-16 hours for the whole bird.

- Batch blast freezer (trolley freezer): small scale process, suitable for batches
- Blast freezing tunnel: large scale process, suitable for continuous production
- Spiral freezer: large scale process, suitable for continuous production

Cold storage: It could be stored either chilled or frozen

- Chilled: 0/+4 ºC. Storage life up to 10 days
- Frozen: –18/–20 ºC. Storage life up to 24 months



MEAT

Chilling: It is essential to be chilled to +5 ºC as fast as possible.

- Blast chilling room: small scale process, suitable for batches. The cooling medium is air.
- Blast chilling tunnel + equalization room: large scale process, suitable for continuous production. The cooling medium is air.

Freezing: It is cooled down to –18 ºC. It could be carried by one of the following methods:

- Batch blast freezer (trolley freezer): small scale process, suitable for batches
- Spiral freezer: large scale process, suitable for continuous production
- Carton freezer: large scale process, suitable for continuous production
- Plate freezer (contact freezer): large scale process, suitable for continuous production

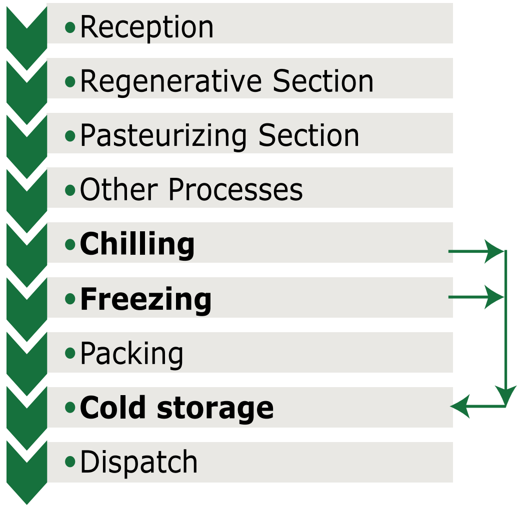
Cold storage: It could be stored either chilled or frozen

- Chilled: 0/+2 ºC. Storage life up to 10 days
- Frozen: –18/–25 ºC. Storage life up to 16 months

APPLICATIONS

FOOD AND BEVERAGES

DAIRY (MILK-BASED PRODUCTS)



Chilling: It is essential to be chilled down to 0/+4 ºC as fast as possible. It could be carried by one of the following methods:

- Ice water: small scale process, suitable for batches. An ice bank works as a thermal storage supplying water at 0.5 ºC to the process
- Brine or glycol: the liquid chilling unit supplies −4/−2 ºC to the process
- Trolley chilling room/tunnel: the finished product is chilled with air

Cold storage: It could be stored either chilled or frozen

- Chilled: 0/+4 ºC. Storage life up to 1 week (for milk)
- Frozen: −18/−20 ºC. Storage life up to 9 months (for butter)

FRUITS AND VEGETABLES

Chilling: It is essential to be chilled down to their optimum storage temperature (it varies in function of the product stored) as fast as possible, within 24 – 72 hours. It could be carried by one of the following methods:

- Pre-chilling: It could be done by hydro cooling (wet cooler), forced air cooling (tunnel) or vacuum cooling
- Room chilling: done in the same room as for storage. Cooling down can be speeded up by high speed fans

Freezing: It is cooled down to the product optimum storage temperature. It could be carried by one of the following methods:

- Fluid bed freezer: large scale process, suitable for continuous production, like small fruits and vegetables
- Blast freezing tunnel: large scale process, suitable for continuous production
- Spiral freezer: large scale process, suitable for continuous production
- Carton freezer: large scale process, suitable for continuous production
- Plate freezer: large scale process, suitable for both batches and continuous production.

Cold storage: It could be stored either chilled or frozen.

- Chilled: −2/+15 ºC. It is often equipped with humidifying equipment and needs to be held in a controlled atmosphere.
- Frozen: −18/−25 ºC.

APPLICATIONS

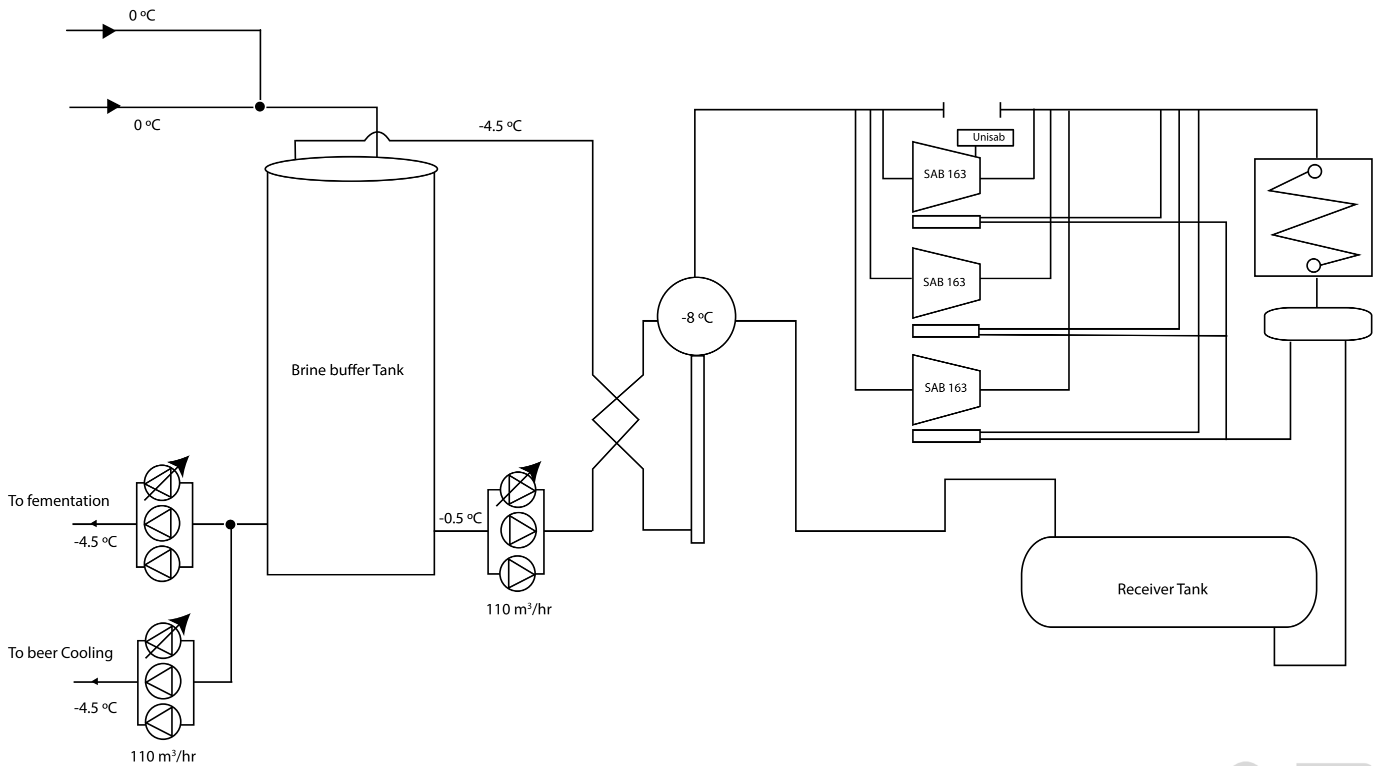
FOOD AND BEVERAGES

BEVERAGES

Refrigeration is an essential utility in the brewing process, since temperature needs to be controlled accurately. In many breweries it is common to operate at one temperature level.

If the brewery is of a certain size, it is more common and economical to split the various requirements into different temperature level systems.

A typical central refrigeration plant for breweries is shown below.



APPLICATIONS

PHARMACEUTICAL AND CHEMICAL INDUSTRIES

Chemical, petrochemical and oil-refining industries often require large refrigeration plants, since some of their important process operations require cooling due to condensation of gases, dehumidification of air, preservation of compounds, etc. These important processes include the following:

1. Liquefaction of gases

It consists of the physical conversion of a gas into a liquid state. Some gases can be converted into liquid with simple cooling, at atmospheric pressure, but most often they require pressurization as well.

2. Solidification of liquids

It consists of the physical conversion of a liquid into a solid state. Transport and storage of certain substances can be held in a more effective way in a solid state, preventing deterioration.

3. Crystallization of salts from solutions

It consists of the formation of a solid where the atoms or molecules are highly organized into a structure known as a crystal. One of the most common ways of forming crystals is precipitating from a solution. Solubility of the solvent usually decreases with the temperature, so lowering the temperature of the dissolution would trigger the crystallization.

4. Regulation of reaction velocities

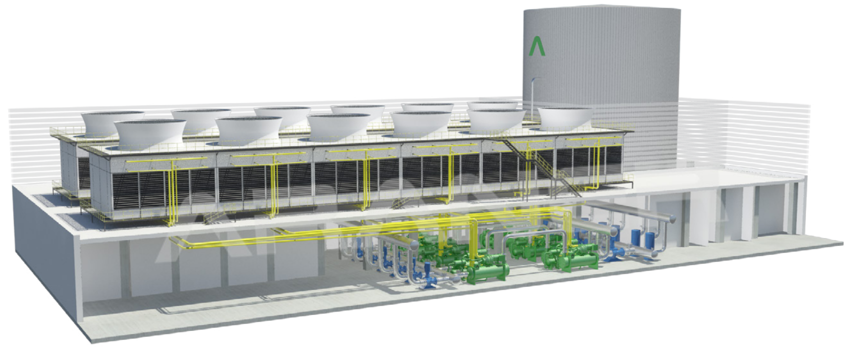
Chemical reaction velocity has a high dependence on the temperature at which it occurs. Therefore, a good temperature control by means of a refrigeration system is required.

APPLICATIONS

DISTRICT COOLING

District Cooling refers to the centralized production and distribution of cooling energy. The cooling energy is produced in a central cooling plant as chilled water and it is distributed to consumers in a closed piping circuit, also known as a reticulation system. The District Cooling market has been expanding continuously in recent years because it has demonstrated itself to be beneficial for the Owner and the Consumer.

On the one hand, for the owner of the DCP, it is a safe business with a quite stable demand and relatively low payback periods. On the other hand, for the consumer, the capital costs and operation costs are reduced. In addition, the cooling equipment, which can be noisy, is usually placed outside the building (sometimes remotely) and maintenance operations are often outsourced.



Learn more about District Cooling Systems **here**

ELECTRICITY PRODUCTION

Gas turbines (aero-derivative or heavy-duty) are constant volumetric air flow machines, yet their power output is proportional to the air mass flow and therefore to the air density. Since air density decreases with higher ambient air temperatures, the result is decreased turbine output. Controlling the input air mass results in stabilizing the inlet air conditions, so that the output of the electrical energy provided by the turbine can be constant.

Having a Turbine Inlet Air Cooling system will allow not only the turbine to have a constant temperature for the inlet air, but an increase of the turbine’s power as well. Since colder air can enter the turbine, it is possible to fit a higher mass of air into the same volume.

Learn more about TIAC systems **here**

RELIABLE AND EFFICIENT COOLING ENERGY PRODUCTION

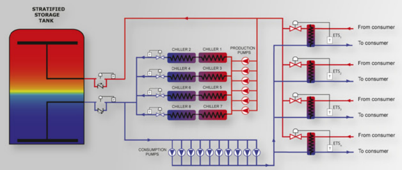
DISTRICT COOOLING PLANT

THE PROJECT

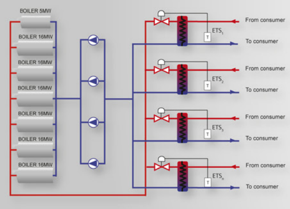
Abdali is Amman's new downtown that provides the Jordanian capital with the central business, social and residential destination it needs as a regional business and tourism hub. Plenty of modern and luxury building, towers, residences, business centers and commercial area have been developed with a total value of more than 5 billion USD.

The relationship beteen ARANER and Abdali started in 2009 with the installation of a temporary District Cooling Plant with a capacity of 2,500 TR. Afterwards a new phase of the plant has been implemented with a total cooling capacity of 31,500 TR; and a second phase will be developed in the near future with a total capacity of 52,000 TR.

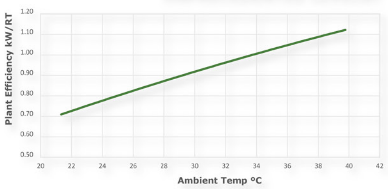
Chilled water system



Hot water system



SPECIFIC CONSUMPTION GOES DOWN TO UNPRECEDENTED LEVELS!!



Main Technical Parameters

Global Plant COP............................4.51 (0.78 kW/ton)
Chilled Water Temperature............4.4 ºC / 13.3 ºC
Peak cooling capacity.....................52,000 Ton
Figure of Merit..............................0.95
Type of Storage............................ Water/Stratified
Total heating capacity...................100,000 kW
Hot Water Temperature................ 60 ºC / 115 ºC

DIRECT CONDENSATION SOLUTION

Due to the water restrictions in Jordan, ARANER developed a solution with ZERO water consumption but with several improvements in order to achieve a yearly efficiency similar to a DC plant with cooling towers. These improvements are as follows:

- Direct Condensation
- Industrial grade high efficiency chillers
- Long term storage tank
- Natural and efficient refrigerant

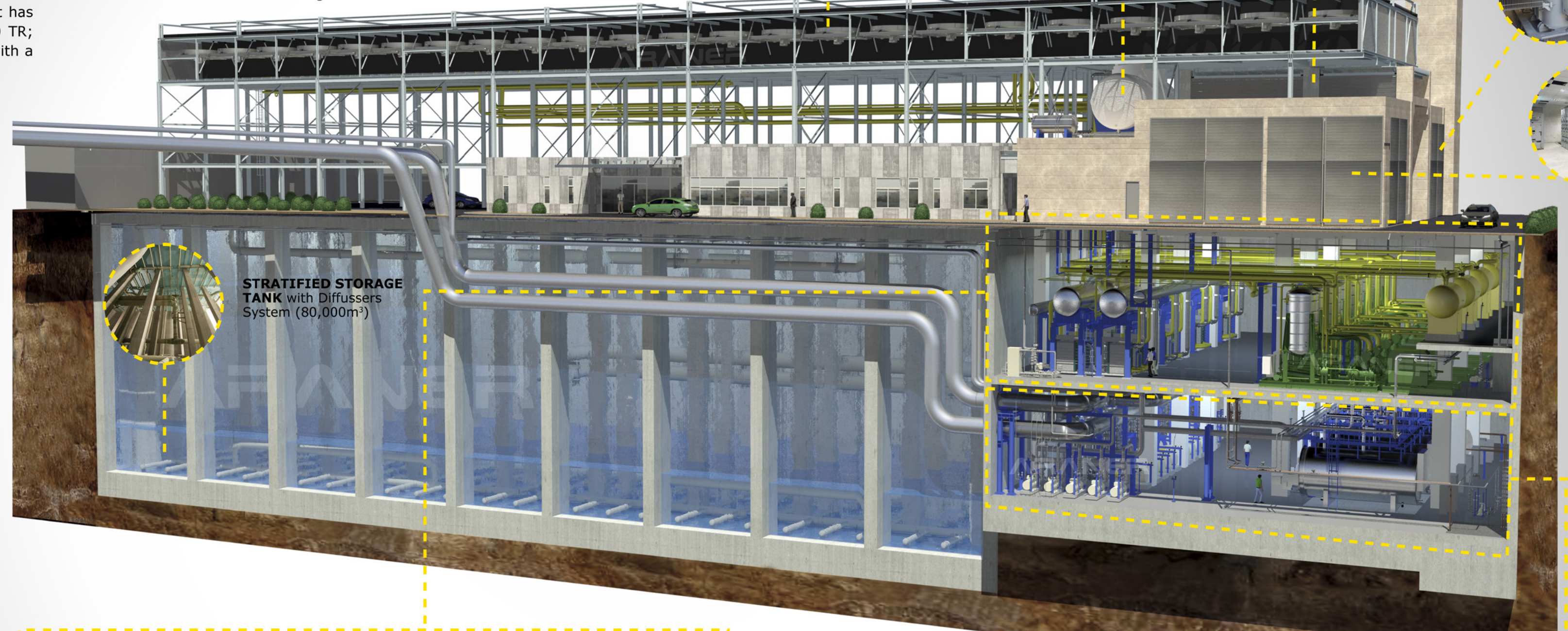
Scrubber
Water Type
VFD in ventilation fans to regulate the air flow

R717 Condensers
Forced Air Cooled
Stainless Steel Tubes
Aluminium finned

Dry Type Transformers

Oil Type Transformers

Low Voltage and Medium Voltage Rooms



Evaporators
Stainless Steel and
Semi-Welded
plate heat exchanger

Compressor Units
Taylor Made Chillers designed and fabricated in Araner's Workshop
2,500 TR Screw Compressor
High efficiency and reliability

Hot Water Pumps
4 on Duty + 1 Standby
Total Flow: 1,560m³/h

Consumption Pumps
9 on Duty + 1 Standby
Total flow: 17,630m³/h

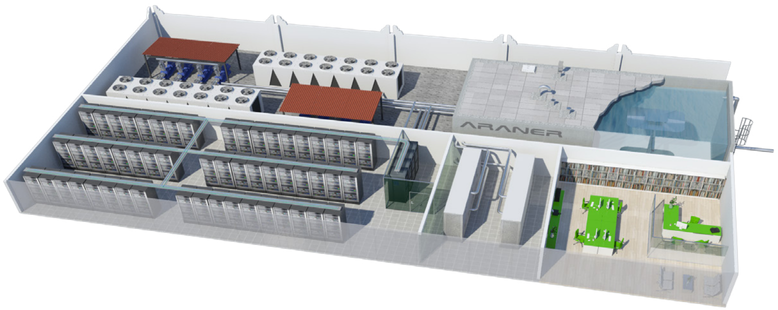
Production Pumps
5 on Duty + 1 Standby
Total flow: 7,140 m³/h

Boilers
6 of 16,000kW
1 of 5,000kW
Dual Fuel & Gas Burners
Minimum Efficiency= 92%

THE WORLD LARGEST THERMAL ENERGY STORAGE WITH STRATIFIED WATER FOR A DISTRICT COOLING APPLICATION

APPLICATIONS

DATA CENTER



A data center is a facility that centralizes an organization's IT operations and equipment, as well as it is where it stores, manages, and disseminates its data. They are mainly composed of electronic devices, which produce a lot of heat as they work, while also being very sensitive to high temperatures. That is why the cooling system plays a key role in the performance of data centers.

NAVAL INDUSTRY

As stated before, the importance of maintaining goods (food, chemicals, etc.) in proper conditions through their transportation is vital in order to be delivered to their destination without any damage. In a globalized world it is very common to use marine transportation, so that every place worldwide can be reached. Moreover, large shipping involved people requires a good HVAC design, due to the small and complex departments inside. This way, good air conditions should be met for the crew and passengers.

OTHERS

To sum up, refrigeration is used extensively and it is an essential part of daily life. It is important to carefyllu study every single project, as the conditions can vary a lot. Not doing this would result in problems and very high costs in the short and long term. Cooling loads subjected to a great variability are often expensive to satisfy. In such cases, the use of a Thermal Energy Storage approach is advisable.

The TES Tank is a thermal accumulator that allows the storage of chilled water or ice produced during off-peak time. This energy is later used during on-peak time. A TES tank reduces refrigerant plant capacity and operational cost, producing chilled water when demand is low, which usually coincides with the night, when ambient temperature is low and chillers have better performance.

Learn more about Thermal Energy Storage [**here**]

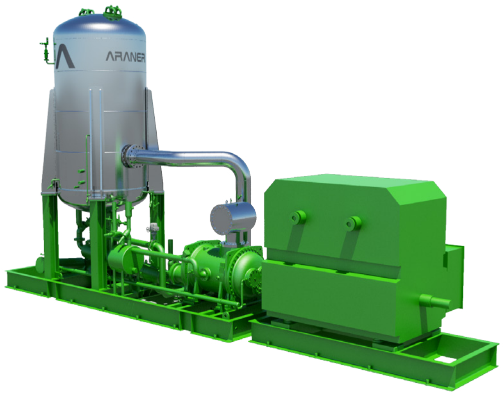
ARANER

COMPONENTS OF THE REFRIGERANT CYCLE

COMPRESSOR

The compressor is a machine that raises the pressure in the refrigerant as it leaves the evaporator. The refrigerant that enters the compressor will be in a vapor phase. To ensure this, the refrigerant gets more heat than theoretically needed to change its phase; that means that the refrigerant will enter the compressor at a temperature slightly higher than the temperature at which it turns into vapor.

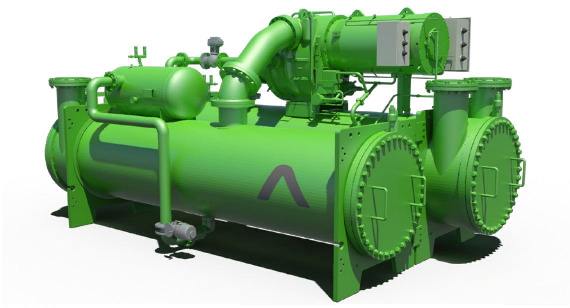
Screw compressor



The compressor comes with both male and female rotors that can either drive each other or rely on a timing gear. Usually, the male rotor connects to the motor, acting as the driving rotor, while the female rotor is driven. As the two rotors rotate, volume in their grooves reduces, thereby compressing the refrigerant. We can describe the operation process in the following stages:

- First stage: the inlet port of the compressor takes the refrigerant
- Second stage: tooth space reduces as the seal line goes in the direction of discharge (compression takes place)
- Third stage: compression continues up to the point where both rotors are at the discharge port (pressure is high at this point)
- Fourth stage: with the seal line at the discharge, the tooth space discharges the refrigerant

Centrifugal compressor

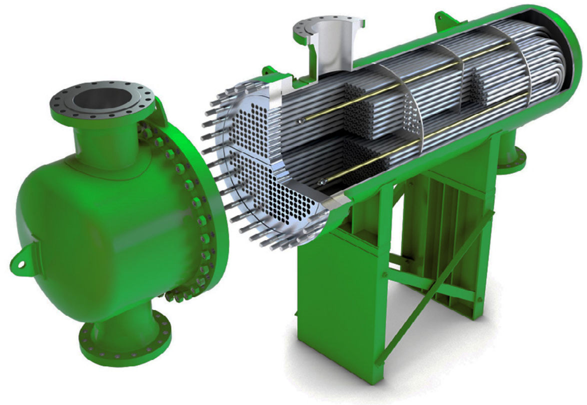


The centrifugal compressor is a dynamic machine where the gas compression is a result of increasing the kinetic energy, which raises the gas pressure.

During operation, the refrigerant enters the impeller wheel through an intake port before flowing into the impellers. As the impellers rotate, they exert centrifugal force on the refrigerant, thereby pressurizing it. Since the force created by an impeller is relatively low, for several cases centrifugal chillers come with several impeller in series.

EVAPORATOR

The evaporator is a heat exchanger for transferring energy from the cold system to the refrigerant, due to the temperature difference. The refrigerant is kept at a low pressure level.



The refrigerant enters the evaporator in its liquid phase, with some of it already in the form of vapor. Its temperature is lower than the one in the cold system, so energy is transferred to the refrigerant. The refrigerant then changes its phase into vapor, so most of the energy is accumulated in the form of latent energy.

CONDENSER

The condenser is a heat exchanger for transferring energy from the refrigerant to the hot system, due to the temperature difference. The refrigerant is kept at a high pressure level.

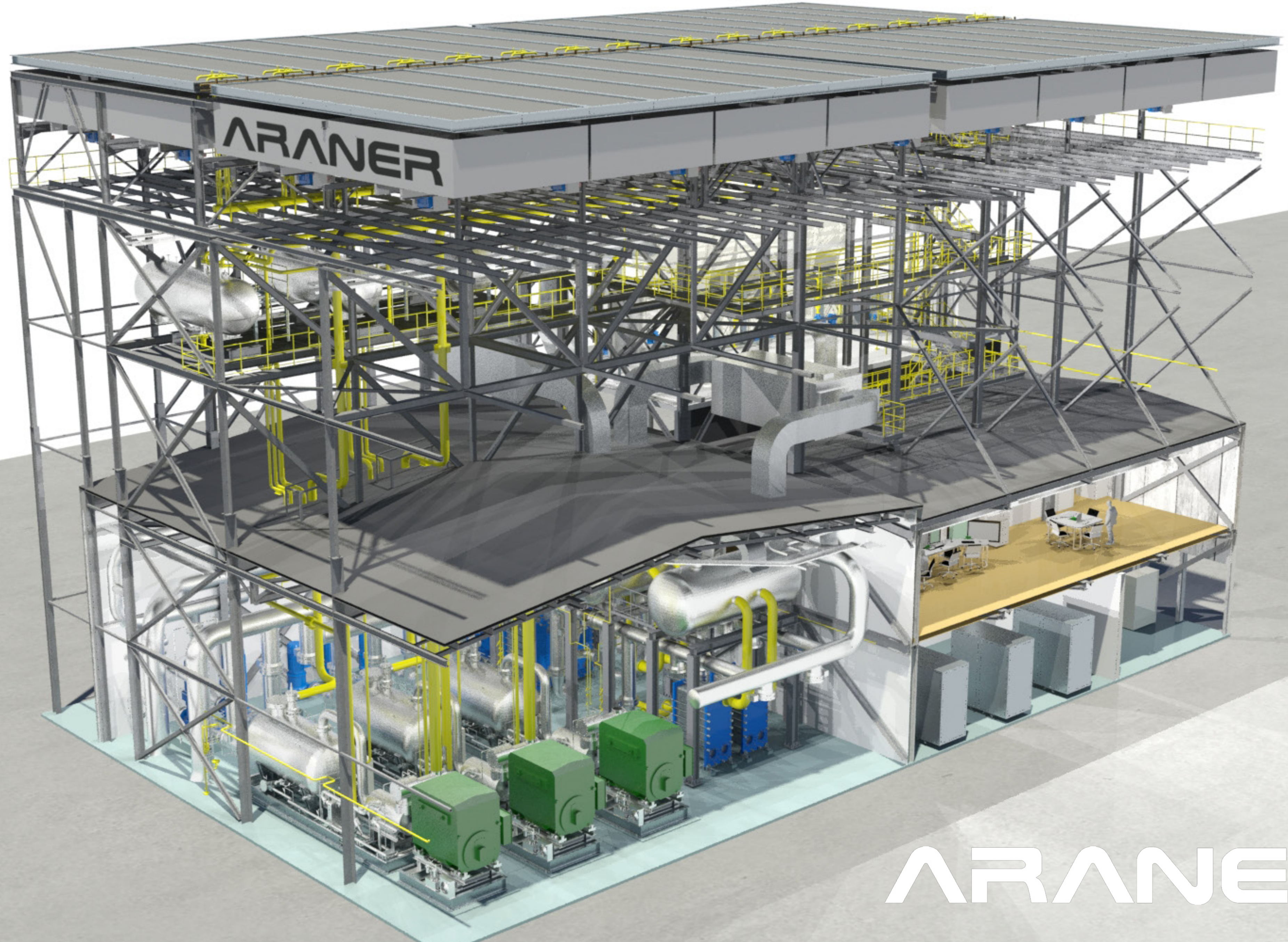
The refrigerant enters the condenser in its vapor phase. Its temperature is higher than the one in the hot system, so energy is transferred to the hot system. The refrigerant changes into its liquid phase, since most of its latent heat is rejected into the hot system. Therefore, the condenser rejects the heat of the process, both the energy removed from the cold system and the energy added to the refrigerant when it was compressed.

EXPANSION VALVE

The expansion valve is a device that connects the high pressure circuit part of the refrigerant with the low pressure circuit part. It implies no energy consumption, since it allows the refrigerant to reach the lower pressure level. This decrease of pressure leads to a lower temperature of the refrigerant.

The expansion valve is controlled depending on the evaporator characteristics:

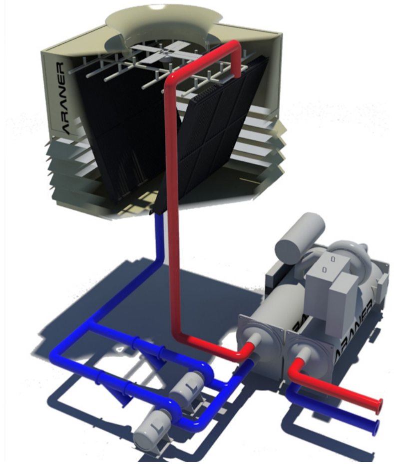
- Direct expansion evaporator: the expansion valve will be controlled by the super-heating of the refrigerant when it leaves the evaporator.
- Flooded flow: the expansion valve will be controlled by the liquid level in the evaporator.


ARANER

TECHNOLOGIES FOR HEAT REJECTION

One of the most important aspects when designing a refrigeration system is the method for rejecting heat that will be used. This aspect is conditional to the plant location and its viability. A suitable technology selection should be done, depending on the particular constrains of each project. ARANER and their expert team will study each project with its unique aspects, so that they can offer their clients a tailor-made solution that fits into their particular needs.

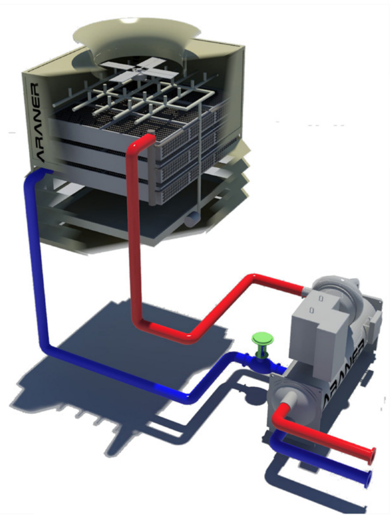
COOLING TOWER



Cooling towers are used extensively in the industrial sector because they are a good method to reject heat to the environment. Cooling towers are available in different types and sizes depending on the load configuration: an important reason to outline the options available. Note that despite the different designs, the basic function remains the same as that of dissipating heat from a building system or a process to the air through evaporation.

Warm water from industrial equipment, commercial AC system or any other heat source enters the tower and spreads evenly at the top. As the water flows down the tower, the equipment filling spreads it over a large area to increase the water-air contact, thus enhancing heat transfer via evaporation.

A large volume of air is constantly moving along the filling, courtesy of large fans in the tower. As evaporation takes place, the water loses heat. It eventually reaches the tower sump at the bottom. The cool water then goes back to cool the initial heat source and the cycle repeats. For the sake of system dilution, a portion of the system water goes to the drain through a bleed-off valve. The makeup line feeds the cooling tower with fresh water for replenishment.



Evaporative condensation

It follows the same principle as the cooling tower, but the fluid that is cooled down is kept in a closed circuit, with no direct contact with the environment. Water is sprayed over the tubes containing refrigerant and an air current favors the evaporation of water. Part of the water used is recovered in the lower basin and can be reused again. Therefore it has as well water losses, same as the conventional cooling towers.

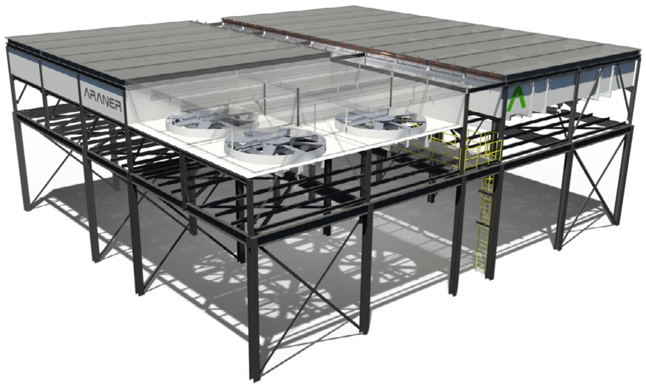
TECHNOLOGIES FOR HEAT REJECTION

AIR CONDENSATION

With this type of condensation, the refrigerant evacuates heat directly into the environment. The refrigerant, when compressed, is driven into the air condensation battery in its gas phase. It transfers heat to a current of ambient air, produced by a fan. This air current is not humidified as in the cooling towers, since air condensation has a zero usage of water. That makes them suitable for applications where the usage of water is restricted.

Normally air condensation is not as cheap and efficient as water cooling can be, but as stated before it has the clear advantage of no water use, which can be a very important requirement for the plant due to the following reasons:

- Better environmental stability - no water wastage
- Low maintenance costs
- Easier to operate and control - absence of tower freezing and tower bypass
- Chemical costs avoided



Nevertheless, ARANER has found a way of combining modern manufacturing methods and advanced technology to achieve highly effective and efficient air-cooled chillers.

Owing to that, ARANER's chiller plants are very competitive to water chilled chillers in different aspects. For example, these plants are very impressive in terms of footprint, efficiency and noise.

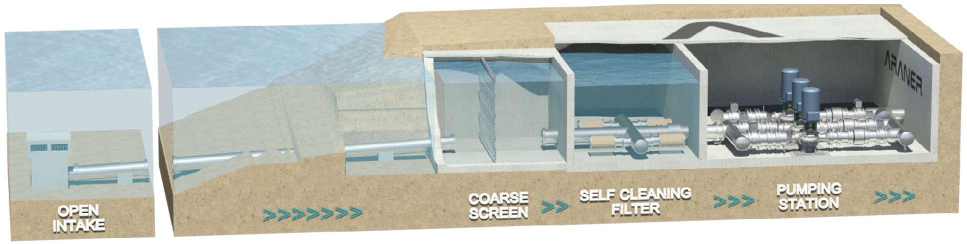

ARANER

TECHNOLOGIES FOR HEAT REJECTION

SEA WATER CONDENSATION

Water from the sea is used for evacuating the heat produced by the chillers. Water is conducted into the cooling plant and heat is transferred from the refrigerant to the sea water. There is no contact between sea water and other fluids (such as refrigerant, oils, etc.) during the process, so water can be released back into the sea with no changes but a slight increase of temperature. The use of sea water condensation is often restricted by the location of the project, since this resource is not available everywhere. Where it can be used, it implies the following advantages compared to conventional air conditioning systems:

- Use of sea water one through as heat rejection method. ZERO desalinated water consumption.
- Elimination of the visual impact, since the sea water cooling system can be integrated inside the cooling services plant.
- Reduced energy consumption, leading to less energy grid requirements, thanks to the improved efficiency.
- Less reliance on fossil fuels.
  - Less air pollution
  - Less global warming impact
  - Less acid rain
- Established cooling technology, widely used in power plants.
- Sustainable and economic method.



The sea water intake point and outfall point are carefully studied, since they are important in order to avoid the malfunction of the cooling plant and to fulfill all the environmental regulations. Therefore, for each particular project there should be elaborated environmental impact studies, geological reports, water quality studies, bathymetric charts elaborations, sea water tides and currents studies, etc. Each project is carefully studied by ARANER so that the best tailor made solution can be provided.

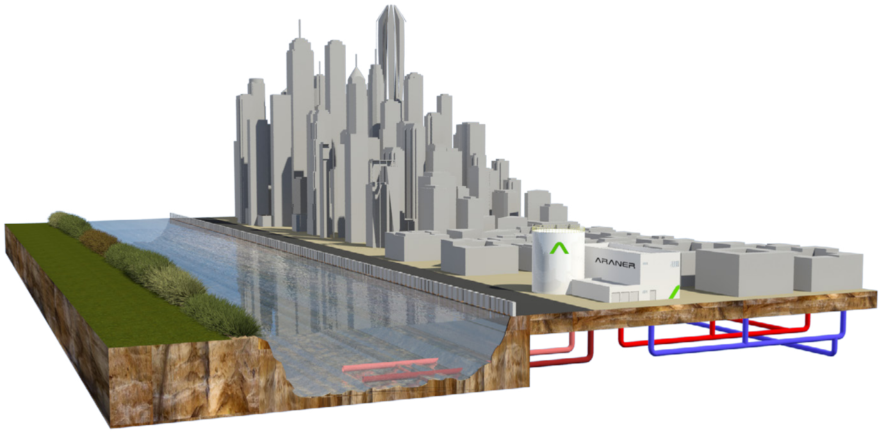
Sea water with a suitable quality for cooling is achieved by means of filtration and antibiofouling. Each system is dimensioned taking into account the above mentioned reports. Both pumps and condensers should be built up of an adequate material for not presenting corrosion and to handle direct condensation. This system is developed by ARANER and it will be integrated into the cooling plant building.

TECHNOLOGIES FOR HEAT REJECTION

RIVER WATER CONDENSATION

River water cooling is a system very similar to the sea water condensation, also with no water consumption and low visual impact. In addition to the advantages of the sea water systems, river water condensation implies the following:

- Less corrosive water, which benefits the system components
- Constant direction of the river flow prevents the recirculation of water, ensuring a good performance of the plant
- Alternative to sea water condensation in locations further away from the sea side



As always when designing a cooling solution that uses water from the environment, special attention should be paid to the particularities of the project. A river water current study, an environmental impact study, a water quality study, etc. should be elaborated, which are required in order to comply with the environmental legislation. Not all the rivers are suitable to be used in this application.

Water is taken from the river with a sufficient height from the river bed in order to avoid sand to coming inside the system, and deep enough to prevent the entrance of lower density debris. Moreover, the intake water speed should be low enough for fish to be able to swim away when they get the feeling that they are dragged by the current. The water is also filtrated, so that suspension solids are removed from the cooling water. After that, water should be treated to avoid the growth of water life inside the system, which could deposit and result of great efficiency losses (great pressure losses, lower heat transmission, etc.). Therefore an antibiofouling system may be used. Water is then pumped into the chiller condenser by means of a pumping group. Both pumps and condenser materials in contact with water should be adequate in order to not present corrosion. Finally, water is returned to the river with a slight increase of temperature, as per environmental legislation. As stated before, the discharge point should be carefully placed with the support of studies. It is also important to diffuse the discharge along the river and not in a single point, since depending on the particular conditions it could have an impact over the river life.

www.araner.com

ARANER